ECONOMIES THROUGH ROOF BOLTING IN AN INDIANA COAL MINE

By L. W. Kelly

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L. W. Kelly 1/

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SUMMARY

The primary purpose of this paper is to show the appreciable savings that were made by roof-bolting the main west entry of the Kings mine, which was to be the permanent, main haulage road, as compared to the cost of supporting the same roof with peg timbering as first planned. Additional items that might prove valuable to other mine operators are contained in this paper and detailed below.

1. A detailed cost of the system of roof support known locally as the peg-timbering method is given. It consists fundamentally of supporting steel cross bars on pegs inserted into holes drilled in the ribs close to the roof.

2. A method of supporting the roof in caved entries is shown, where such support must endure for an extended period in haulageways and air courses.

3. A graphic illustration pictures the difference in the amount of material necessary to support the roof in a cavity by roof bolting and by conventional timbering.

4. A protective scaffold that is installed about 8 feet from the floor in places that have caved to heights of from 15 to 25 feet is described. This is known locally as "snow shedding," and its purpose is to protect mortormen, other haulage employees, and men riding in man-trips from falling pieces of rock.

In view of the fact that at some time or another virtually every coal mine faces the problem of securing the roof permanently in an entry that has caved in places, it is hoped that the successful solution of the problem as described in this paper will benefit other coal-mine operators.

INTRODUCTION

The first roof bolts used in an Indiana coal mine were installed in the Wabash mine of the Snow Hill Coal Corp., Terre Haute, Ind., in March 1949. Since that time their use has increased rapidly, and on June 1, 1952, 471,670 bolts had been installed in the State. Some failures have occurred in different mines from various causes; but, in general, roof bolting has been successful.

The installation described in this paper can be said to be completely successful, as it is doubtful if 100 pounds of rock has fallen in 2-1/2 miles of entry in approximately 18 months.

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Since the primary purpose of this paper was to show the amount of money that could be saved by using roof bolts instead of peg timbering, a very careful study of the costs of peg timbering was made from the payroll records of two Indiana mines that had used this method of roof support for years. It was necessary to obtain an accurate cost of this method of roof support in entries that had not caved in order to form a base to use in calculating the cost in caved areas. It was also necessary to know the accurate cost of roof bolting, and this was arranged at the inception of the project.

The figures in this paper are conservative estimates of costs, and, therefore, it is thought that the figures shown in this publication can be used with confidence by any mine operator confronted with the same problem.

ACKNOWLEDGMENTS

This circular was made possible by the generous cooperation of Placide Mayeur, superintendent, Kings mine, Princeton Mining Co., and G. F. Bieler, general superintendent, Snow Hill Coal Corp. The information and time generously given by these two men are acknowledged gratefully.

GENERAL INFORMATION

Kings mine is in Princeton, Gibson County, Ind. It was opened in 1923, and, at the present time, there are three shafts ranging in depth from 450 to 465 feet. The mine is developed in the Indiana No. 5 coal bed, which averages 72 inches in thickness in the area involved. The maximum cover is about 470 feet. The average daily employment is 473 men, and, of this number, 378 work in the mine. The average daily production of coal is 4,780 tons, all of which is loaded mechanically and broken down with Airdox. The life of the mine is estimated by the officials to be 14 years.

The room-and-pillar method of mining is followed, and the pillars are not extracted. The entries are driven 12 to 16 feet wide on 40-foot centers, and the rooms are driven 26 feet wide on 44-foot centers.

The mine is ventilated with one axial-flow fan and one centrifugal fan, both operated blowing. The coal is hauled by shuttle cars, trolley, and cable-reel locomotives and hoisted to the surface preparation plant through a shaft. Electric power, 2,300-, 440-, and 220-volt alternating current and 275-volt direct current, is used on the surface and in the mine. Fire-fighting equipment is adequate.

CHARACTER OF ROOF AND TIMBERING METHODS

The roof varies greatly from area to area; but, in the section involved, it consists of 12 inches of hard, black shale overlain successively by 14 inches of hard sand shale and 82 inches of hard gray shale. All of the shales are laminated in various thicknesses. This roof falls readily if not supported and, in general, falls in a series of benches, as shown in figures 1, 2, 4, and 5.[2/] However, when it falls to heights of 15 feet or more, it arches as shown in figure 7.

2/ It should be noted that the photographs (figs. 5 and 7) were taken directly after the construction work was finished and before the mine roadway had been cleared of debris.

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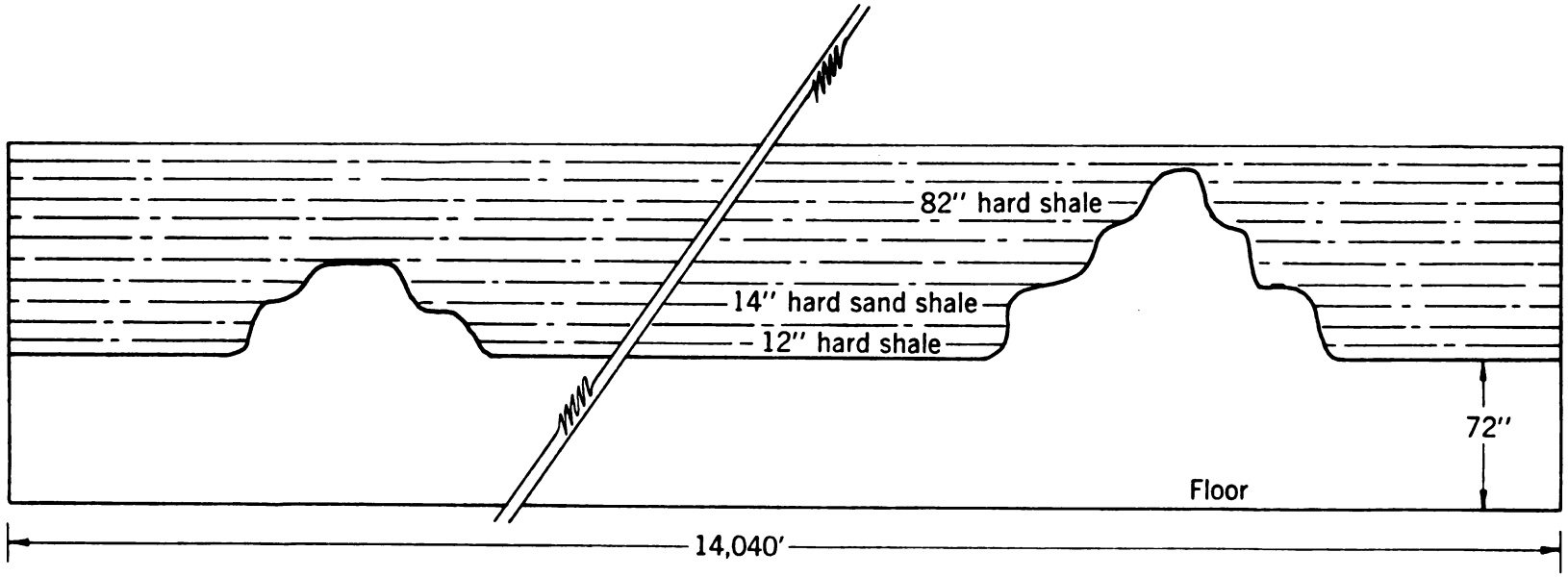

Figure 1. - Representative roof section and profile before roof bolting, Kings mine.

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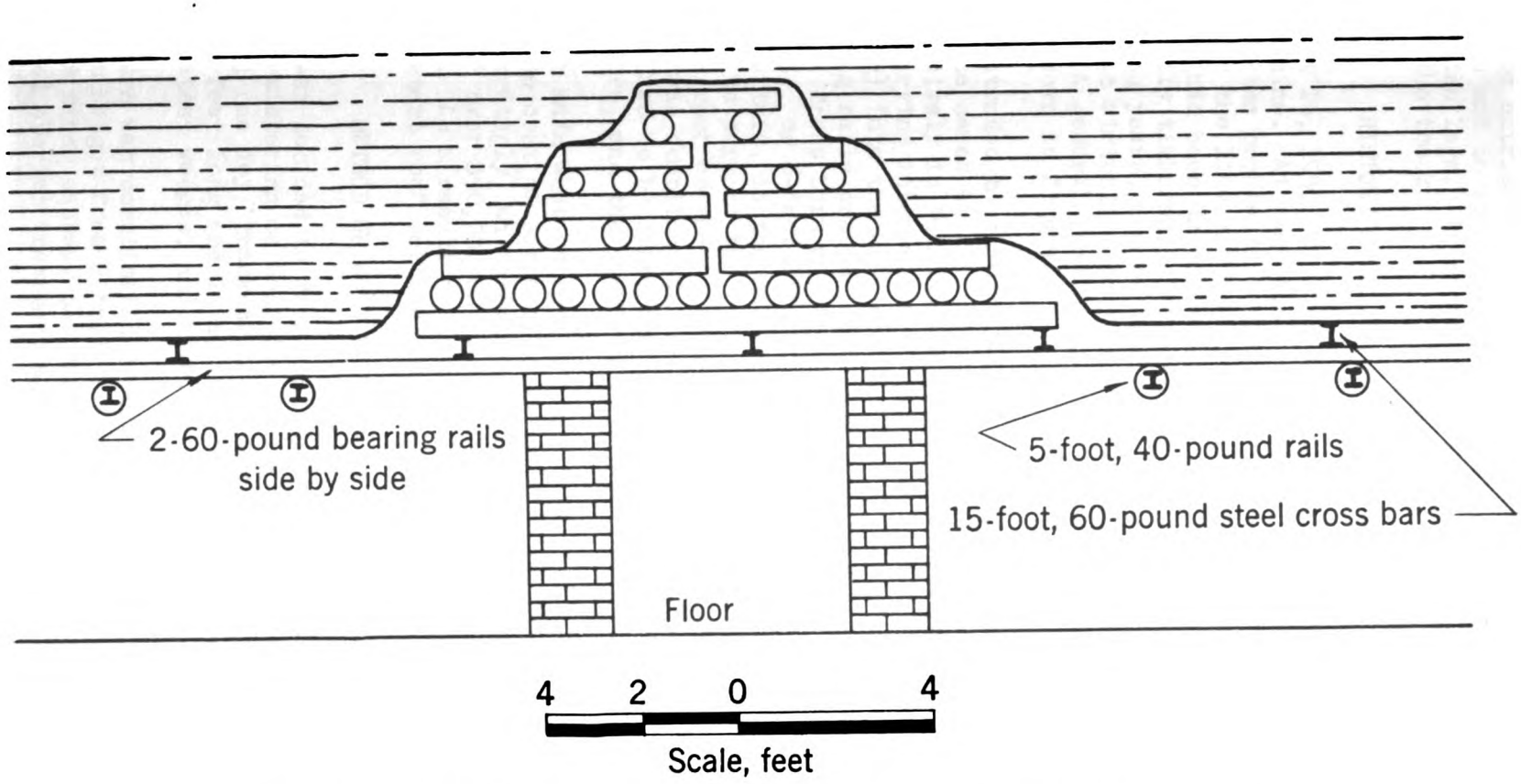

Figure 2. - Method of supporting the roof by peg timbering in a crosscut, Kings mine.

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A systematic method of timbering has been adopted. Where cross bars are needed, steel rails of heavy, cross-sectional area are used to a great extent. In main haulage entries these are installed by the peg-timbering method. In working places and to some extent in haulage roads, the cross bars are supported by wooden legs. In rooms, two rows of posts 5 feet apart are set on each side of the track.

HISTORY OF ROOF BOLTING IN THE KINGS MINE

On August 16, 1950, the first conversations regarding roof bolting were held at this mine. At that time, the superintendent of the mine, Placide Mayeur, faced the problem of supporting the roof in what was to be the main motor road for the life of the mine. This entry, the main west, was 14,020 feet long and had been driven several years before when the mine had been only temporarily timbered. There were 230 crosscuts in the entry, and, in the intervening years, a cave ranging in height from a few feet to 25 feet had occurred at virtually every crosscut. Fairly good roof remained between these caves. A general idea of the condition of the entry with respect to the roof is shown in figure 1.

Mayeur intended to support the roof permanently by using peg timbering and lagging the caves at the crosscuts with wood. The peg-timbering method is used extensively in Indiana and Illinois and consists of drilling holes in the ribs at varying intervals and inserting a piece of steel rail (known locally as a peg) into the hole so that 1 to 2 feet of the peg extends into the entry. Bearing rails are placed on the pegs parallel to the ribs on each side of the entry. Cross bars of 60-pound steel are then placed on the bearing rails at 4-, 5-, or 6-foot intervals, depending on the character of the roof. In addition to this, in the main west entry, the caves at the crosscuts were to be cribbed to support the roof at the top of the cavities. This method of supporting the roof at the crosscuts is shown in figure 2. Roof support at the crosscuts was complicated further by the fact that the long span of the bearing rails had to be supported by brick piers. The wide crosscuts required two piers, and the narrow ones required one. (See fig. 2.)

After the main west entry had been surveyed, it was decided to prepare an estimate of the cost of supporting the roof by peg timbering and also by roof bolting. Accordingly, an estimate was made, and a comparison of the figures indicated that over $50,000.00 could be saved by using roof bolts instead of peg timbering. As a result of this estimate, Mayeur ordered the necessary equipment to start roof bolting, and on November 10, 1950, the work was begun.

METHOD OF ROOF BOLTING IN THE KINGS MINE

When it was decided to roof bolt the main west haulage road instead of using the peg-timbering method, the following equipment was purchased: One Le Roi Stoper; one Joy, track-mounted compressor; model 120; and 14,000 wedge-type bolts, 4 feet long and 1 inch in diameter, complete with 6- by 6- by 3/8-inch steel plates, wedges, and nuts.

The pattern was complicated because caves occurred at almost every crosscut ranging in height from 2 feet to 9 or 10 and because, in some places, owing to grading and other causes, the vertical distance reached 25 feet. These places required special treatment and will be discussed in detail later in this paper.

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The term "straight entry" used from time to time in this paper refers to that portion of the roof that was undisturbed between the falls in which a regular pattern of roof bolting could be followed. The caves at the crosscuts will be divided into those that would have required one brick pier and those that would have required two brick piers if peg timbering had been used. In the very high places a roof of 2-inch oak planks was erected to protect the motormen, the men in man-trips, and others traveling the main west entry.

The straight entry involved 7,660 feet in all, and a pattern was adopted using three roof bolts in a set spaced 2-4-4-2 every 4 feet along the entry. (See fig. 3.)

The caves at the crosscuts varied in height and extent, depending on the width of the crosscut. The roof caved in a series of distinct benches, as shown in figures 1, 2, 4, 5, and 6. The roof-bolting pattern in the caves was roughly a series of concentric ellipses spaced so that one elliptical set of bolts was installed in each bench. Whether it was a one-pier crosscut or a two-pier crosscut, the same procedure was followed. (See figs. 3, 4, and 5.) In the very high places (see figs. 7 and 8) the same general pattern was followed, although the roof in these places arched instead of caving to benches.

There were a number of places in the main west entry where, owing to various causes, such as grading, a mine fire, and very bad roof, the tops of the caves were 25 feet above the floor. It was obvious that this high roof, even if it were roof-bolted, would always present a hazard to haulage employees, men riding in man-trips, and others whose duties required them to traverse the entry. Consequently, as a safety measure, it was decided to erect a protective scaffold about 8 feet above the floor under the roof bolts, so that any pieces of rock falling from the top would be caught on the scaffold and not fall through to the roadway below. This method is known locally as snow shedding. The snow sheds are erected by drilling holes in the ribs approximately 5 feet apart, inserting 5-foot sections of steel rails, which support steel bearing rails parallel with the ribs. Steel cross bars are set on the bearing rails at 5- or 6-foot intervals and are covered with 2-inch planks set edge to edge. These snow sheds are shown in detail in figures 6, 7, and 8. Obviously, the cost of this protection was high; but, in order to avoid any possibility of criticism, it was included in the total roof-bolting cost of the project, without attempting to show a lower cost for roof bolting.

The roof-bolting crew on the entire installation consisted of one foreman and two drillers. Wedge-type steel bolts 1 inch in diameter and 4 feet long were used throughout. Steel plates 6 inches square and 3/8 inch in thickness were used with the bolts. The bolts were seated with the stoper, and the nuts were tightened with an impact wrench. In the 7,660 feet of straight entry the bolts could be installed handily from the floor with the stoper. When the job was first projected, it was decided to take an old loading machine and convert it into a device to raise the driller into the caves to roof-bolt the cavities. However, owing to lack of material, this idea was discarded, and the high bolts were installed by putting a platform on a mine car, cribbing up to the cavity, or working on top of the fallen rock. For this reason, the rate of roof bolting (58 bolts in one shift for 3 men) was low. Regardless of the difficulties, the officials and men who worked on this job are entitled to a great deal of

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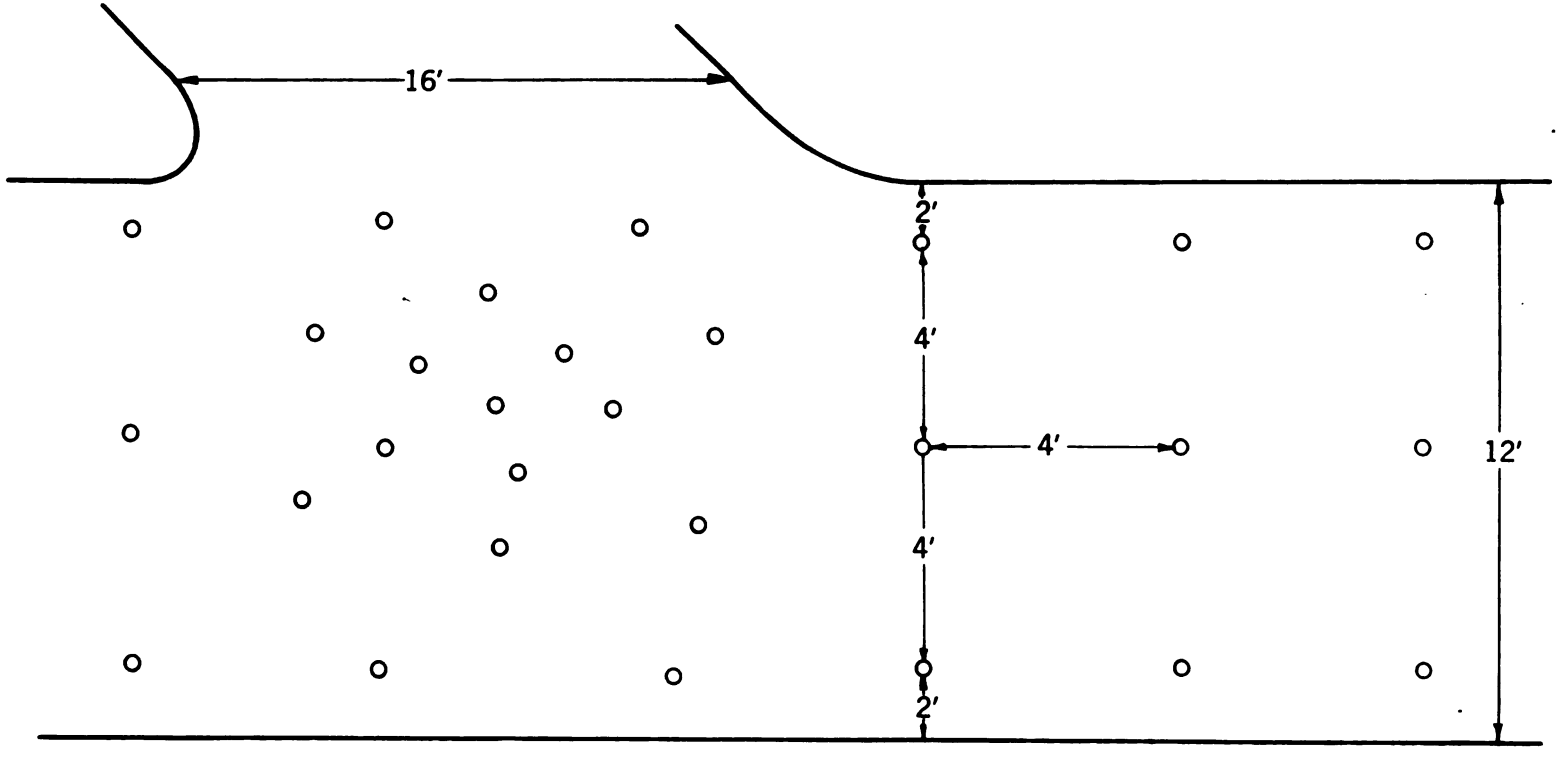

Figure 3. - Pattern of roof bolting for the straight entry and a general pattern for the caves at the crosscuts, Kings mine.

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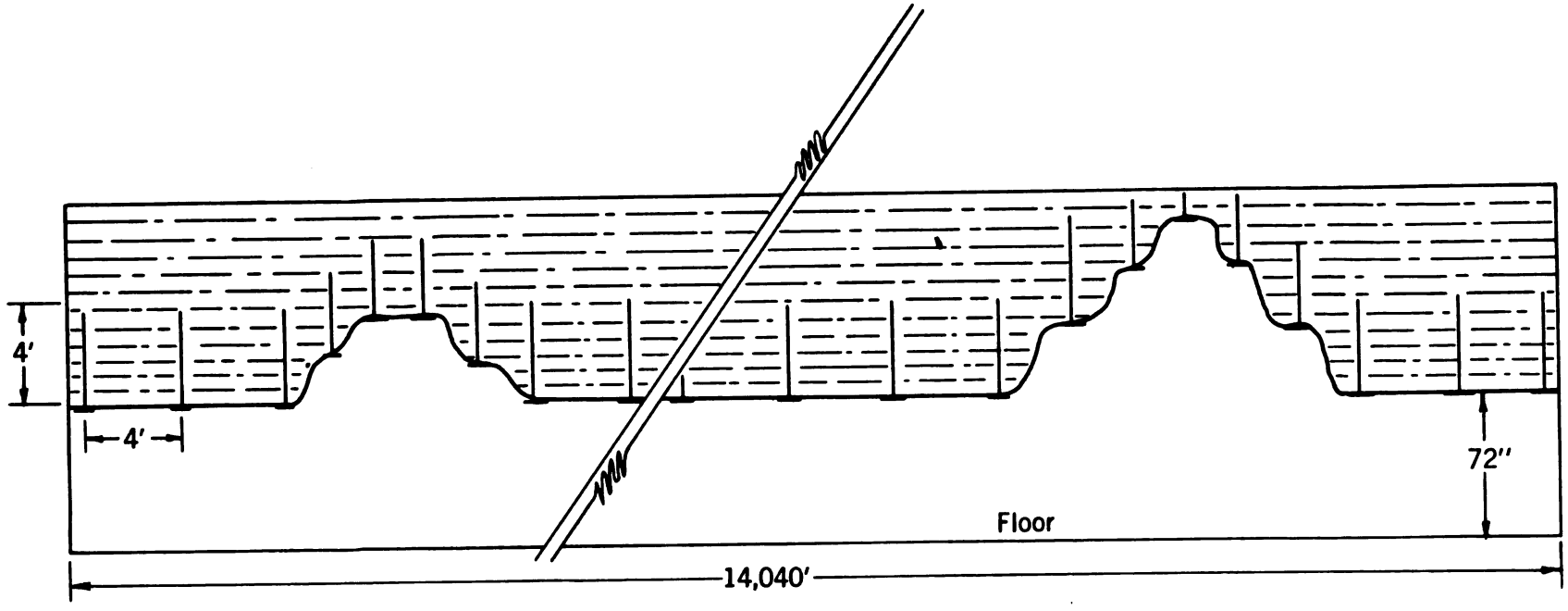

Figure 4. - Representative roof-bolted section, Kings mine.

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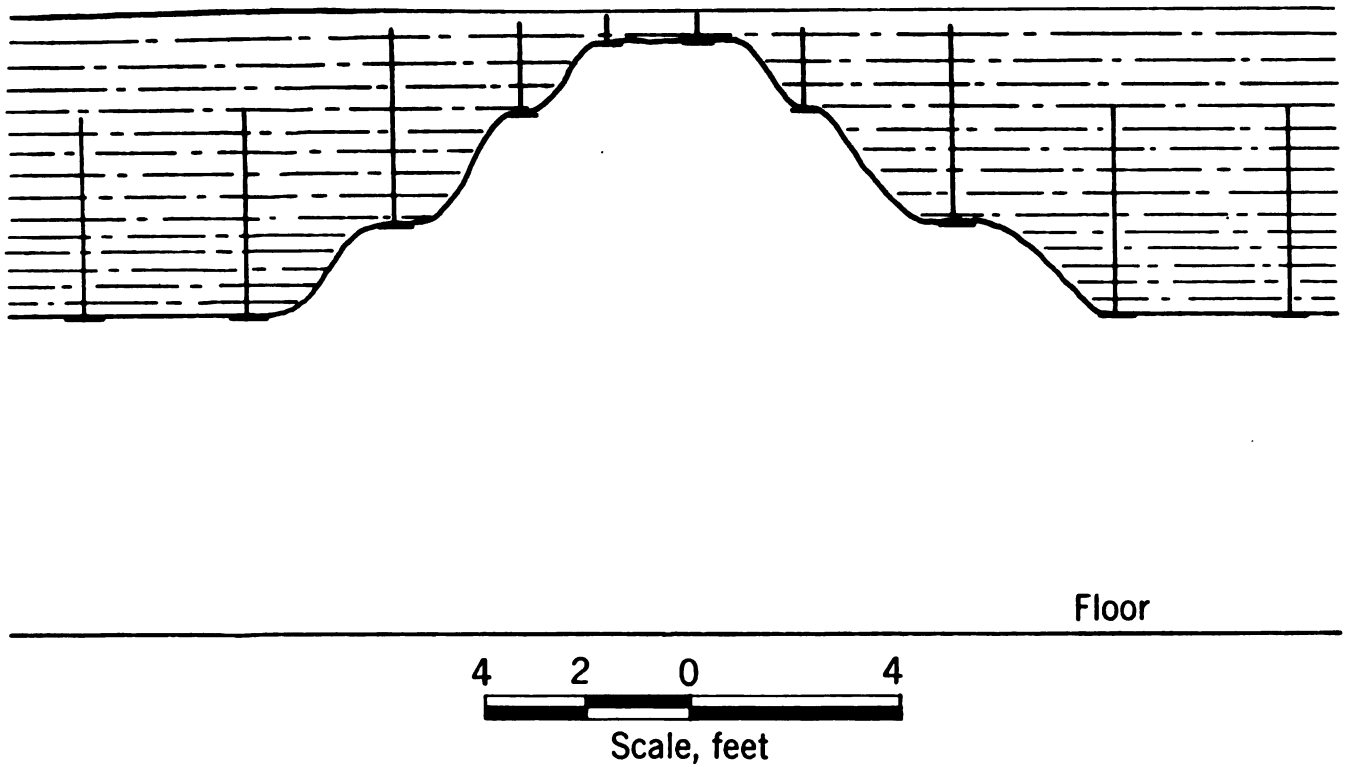

Figure 5. - Method of supporting the roof with bolts at a crosscut, Kings mine.

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Figure 6. - Showing protective covering in moderately high roof-bolted area.

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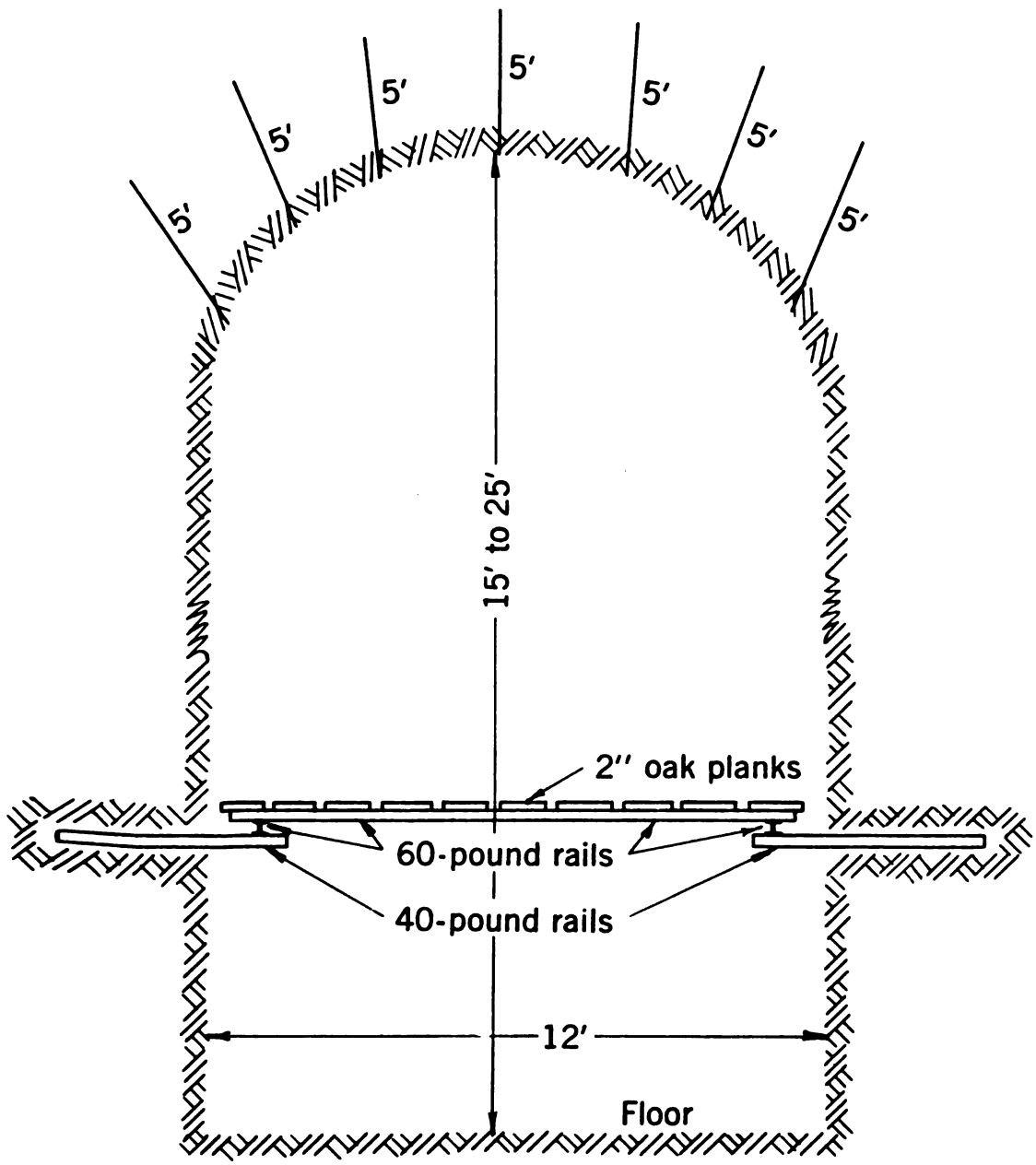

Figure 7. - Sketch showing method of roof support in very high places, Kings mine.

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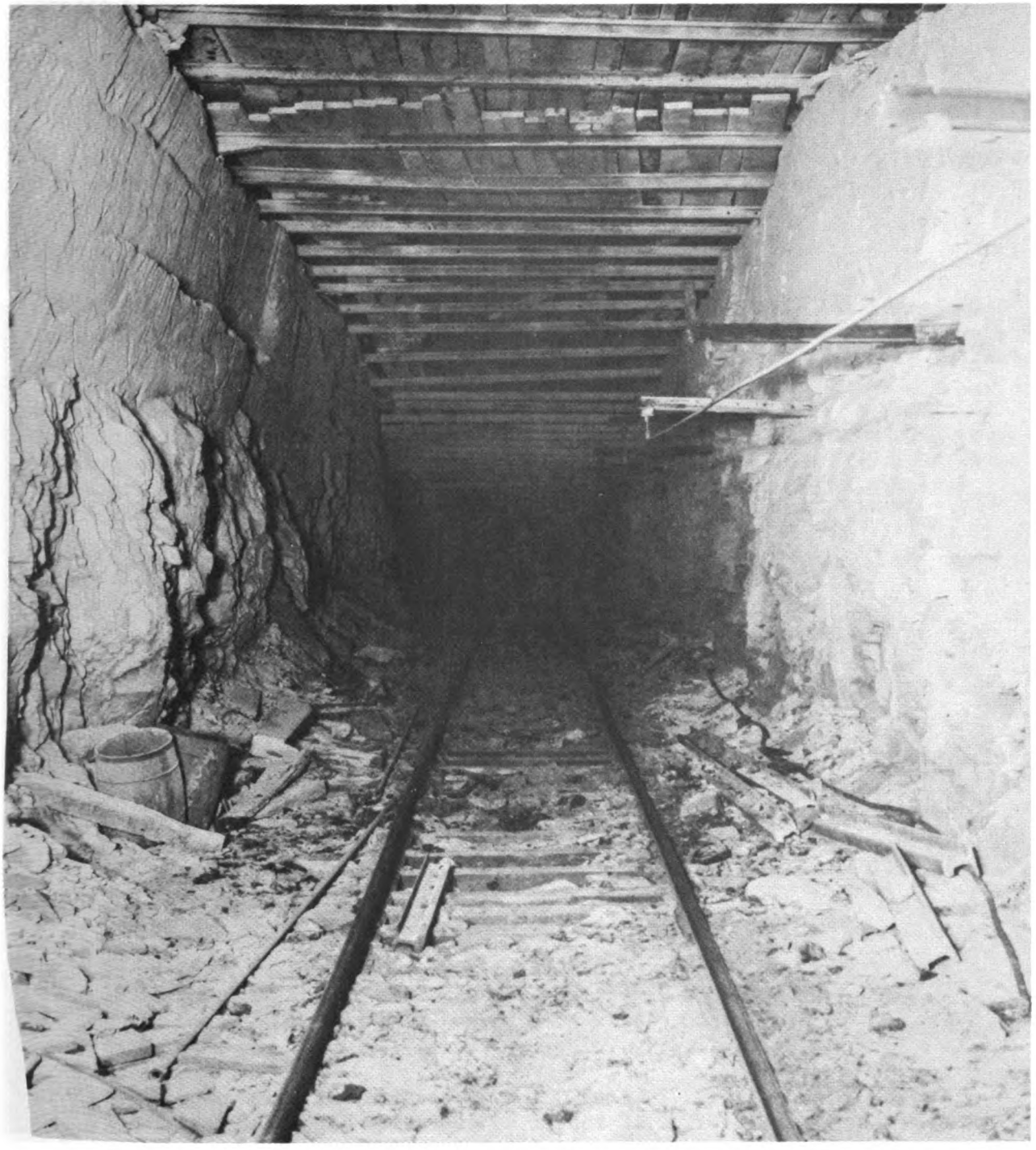

Figure 8. - Showing protective covering in a very high roof-bolted place.

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credit because all of the bolts were installed in an efficient and workmanlike manner. In the entire 2-1/2 miles, there is no evidence of slovenly work, or any attempt to save money by skimping on the number of roof bolts installed in the difficult places. Numerous torquemeter tests were made from time to time during the 18 months required for the job, and they averaged 200 foot-pounds.

As evidence of the integrity of the work done on this installation, there has never been a bolt failure, and the amount of rock that has fallen in the 2-1/2 miles is less than 100 pounds.

METHOD OF ESTIMATING COST

The Kings mine, Princeton Mining Co., and the Snow Hill Coal Corp., have installed thousands of feet of peg timbering in the last 20 years, and the following costs are taken from their actual experience. In comparing the following costs per mile, it must be borne in mind that these values are for straight roof-control in entries where falls have not occurred. However, in the Kings mine, where there were falls at every crosscut, complications arose, which increased the cost. This will be considered later. The following estimates are to form a cost base for the unusual conditions in the Kings mine, which will be detailed later in this paper.

TABLE 1. - Requirements for roof support in Wabash mine, Snow Hill Coal Corp., Terre Haute, Ind.

(100 feet of entry; cross bars spaced 4 feet apart):

Labor	
2 men at $16.30 a shift will drill 25 peg holes in 1 shift. Cost per hole $1.30; 36 holes required at $1.30	$ 46.80
To erect steel, including pegs, bearing rails, cross bars, and wedges, requires 5 man-shifts at $16.30	81.50
Total labor	128.30
Material	
36 5-foot, 40-pound, steel rails at $50.00 a ton	$ 60.00
18 11-foot, 60-pound, steel bearing rails, at $75.00 a ton.	148.50
25 12-foot, 60-pound, steel cross bars at $75.00 a ton	225.00
Total	433.50
Total cost labor and material for 100 feet	$561.80
Total cost labor and material for 1 foot	$5.61
Total cost labor and material for 1 mile	$29,620.80

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TABLE 2. - Requirements for roof support in the Kings mine, Princeton Mining Co., Princeton, Ind.

(75 feet of entry; peg-timbering method; cross bars spaced 5 feet apart)

Labor

2 men at $16.35 a shift will drill 22 6-foot peg holes in 1 shift.		
Cost of drilling 1 hole	$1.49	
Cost of drilling required 32 holes		$47.68
4-1/2 man-shifts at $16.35 required to erect steel for 75 feet of entry		73.58
Total labor cost		121.26

Material

15 cross bars, 12 feet long, 60-pound steel, at $75.00 a ton	$135.00
10 bearing rails, 12 feet long, 60-pound steel, at $75.00 a ton.	90.00
32 pegs, 5 feet long, 40-pound steel, at $50.00 a ton	26.67
Total material cost	251.67

Total material and labor cost for 75 feet of entry	$372.93
Cost for 1 foot of entry	$4.97
Cost for 1 mile of entry	$26,241.60

A study of the foregoing costs per mile for peg timbering in two different mines will show that the two costs compare very favorably. The higher cost at the Wabash mine is due to the fact that the cross bars are spaced at 4-foot instead of 5-foot intervals, as at the Kings mine.

The price of the steel that would have been used for the peg timbering is based on the value of scrap steel and not on the prevailing price of new steel. Even so, the prices used are below the cost of good used steel. Such incidental costs as preparing, handling, and transporting the materials into the mine and the cost of the sand used in building the brick piers are not included.

Of the 230 crosscuts in the 14,020 feet of entry, 115 required 2 brick piers each, and 97 required 1 brick pier. The difference lies in the fact that 115 of the crosscuts are 16 to 18 feet wide because they were driven at an acute angle, and 97 are about 12 feet wide, being driven at 90° from the entry. Each crosscut required unit roof support of 30 feet of entry; consequently, 6,360 feet of entry required special roof support, and 7,660 feet required the conventional peg timbering.

The method of supporting the entry roof at a 16- to 18-foot crosscut requiring two brick piers is as follows: Four 6-inch holes 6 feet deep are drilled in the rib on the crosscut side of the entry, and six are drilled on the solid side. Five-foot lengths of 40-pound steel (pegs) then are inserted into these holes, and, on the crosscut side, two 60-pound, steel bearing rails are placed on the pegs side by side to go over the open span of the crosscut. On the solid-rib side, one 60-pound bearing rail is placed on the six pegs. Five 60-pound steel cross bars then are installed on the bearing rails. To

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secure the roof in the cavity above, wooden posts are used for cribbing on the steel cross bars. The number of posts used varies with the size of the cavity; but, on an average, 100 posts are used at each crosscut. For details of this installation, see figure 2. A graphic illustration of the difference in the amount of material necessary to secure the roof in a caved area using the two methods of roof support can be seen by comparing figure 2 with figure 5.

In tables 3 and 4, which follow, the cost of supporting the roof at the crosscuts is estimated. There were 115 crosscuts that required 2 brick piers each and 97 that required 1 pier to support the roof of the caves properly at the crosscuts. Since 30-foot bearing rails were required, this support at the crosscuts also supported the roof of 30 feet of entry at each crosscut. Eighteen of the 230 crosscuts required straight-roof support only, eliminating the cost of cribbing and brick piers for 540 feet.

The net result was that, of the 14,020 feet of entry, 7,660 feet required straight peg timbering, 3,450 feet required cribbing with two brick piers, and 2,910 feet required cribbing with one brick pier. The cost of the special treatment is itemized in tables 3 and 4.

TABLE 3. - Estimate of cost of roof support with peg timbering at crosscuts requiring one brick pier

(Each crosscut involves the roof support of 30 feet of entry or a total of 2,910 feet)

Material			
3	30-foot, 60-pound, steel bearing rails at $75.00 a ton	$67.50	
5	15-foot, 60-pound, steel cross bars at $75.00 a ton ..	56.25	
10	5-foot, 40-pound, steel pegs at $50.00 a ton	16.66	
100	7-foot posts for cribbing at $0.28	28.00	
	Total cost of steel and wood		$168.41
Labor			
Drilling 10 6-foot peg holes at $1.49		14.90	
Installing wood and erecting steel, 4 man-shifts at $16.35		65.40	
	Total labor cost, exclusive of piers		80.30
	Material and labor cost for 1 brick pier		
Material			
252 bricks at $0.025		6.30	
2 sacks cement at $1.10		2.20	
	Total material cost for 1 pier		8.50
Labor			
1-1/3 man-shifts at $16.35 to build 1 pier			21.80
Total labor and material cost for supporting roof at 1 1-pier crosscut			279.01
Total labor and material cost for supporting roof of 97 crosscuts, which is equivalent to supporting 2,910 feet of entry roof			$27,063.97

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TABLE 4. - Estimate of cost of roof support with peg timbering at crosscuts requiring two brick piers

(Each crosscut involves roof support of 30 feet of entry, a total of 3,450 feet)

Material			
3	30-foot, 60-pound, steel bearing rails at $75.00 a ton	$67.50	
5	15-foot, 60-pound, steel cross bars at $75.00 a ton ..	56.25	
10	5-foot, 40-pound, steel pegs at $50.00 a ton	16.66	
100	7-foot posts for cribbing at $0.28	28.00	
	Total cost of steel and wood		$168.41
Labor			
	Drilling 10 6-foot peg holes at $1.49	14.90	
	Installing wood and erecting steel, 4 man-shifts at $16.35	65.40	
	Total labor cost, exclusive of piers		80.30

Material and labor cost for 1 brick pier (2 required)

Material			
252	bricks at $0.025 for 1 pier	6.30	
2	sacks cement at $1.10 for 1 pier	2.20	
	Total material cost for 1 pier	8.50	
	Total material cost for 2 piers	17.00	
Labor			
1-1/3	man-shifts at $16.35 for 1 pier	21.80	
	Labor for 2 piers	43.60	
	Total labor and material cost for 2 piers		60.60
	Total labor and material cost for supporting roof at 1 2-pier crosscut		309.31
	Total labor and material cost for supporting roof at 115 crosscuts, which is equivalent to supporting 3,450 feet of entry roof		$35,570.65

To complete the estimate for the total cost of supporting the roof in the entire 14,020 feet of the main west entry, it is necessary to find the cost of the 7,660 feet that required straight peg timbering. Table 2 shows that the estimated cost for supporting the roof in 1 foot of straight entry was $4.97; consequently, for 7,660 feet, the cost was $38,070.20.

To estimate the total cost of supporting the roof by the peg-timbering method for the entire main west entry, the three different factors in the total cost are given in the following table. (No. 5.)

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TABLE 5. - Estimate of cost of roof support with peg timbering in Kings mine, Princeton Mining Co., Princeton, Ind.

(14,020 linear feet of roof)

Cost of securing roof in 2,910 feet of entry (1 pier) (from table 3)	$27,063.97
Cost of securing roof in 3,450 feet of entry (2 piers)(from table 4)	35,570.65
Cost of securing roof in 7,660 feet of straight entry	38,070.20
Total estimated cost of securing roof in 14,020 feet of entry..	$100,704.82

When the roof-bolt installation in the main west entry was begun on September 6, 1950, it was important to the company officials that an accurate cost record be kept so that, when the job was completed, a comparison could be made with the estimated cost of the peg-timbering method. Consequently, payroll records were kept and the final cost is shown in table 6, which follows:

TABLE 6. - Cost of roof bolting main west entry, Kings mine, Princeton Mining Co., Princeton, Ind.

(13,950 roof bolts and 14,020 linear feet of entry roof)

Material cost

1 1-inch steel bolt, 48 inches long, slit for 6 inches on 1 end and threaded on other. This includes nut	$1.27
1 6-inch by 6-inch by 3/8-inch steel plate	.35
1 3/4-inch square steel wedge, 6 inches long	.18
Total material cost for 1 bolt	1.80

Labor cost

2 men at $16.35 a day and 1 foreman at $18.71 a day installed an average of 58 bolts in 1 shift.	
Total labor cost for 1 bolt	$0.887
Total labor and material cost for 1 bolt	$2.687
Total cost for installing 13,950 roof bolts	$37,483.65

The final indicated savings for supporting the roof in the main west entry using roof bolts instead of the proposed peg-timbering method are:

Total cost, using peg timbering (table 5).....	$100,704.82
Total cost, using roof bolts (table 6)	37,483.65
Indicated saving	63,221.17

DISCUSSION

The primary purpose of this paper was to show in detail that a comparatively large amount of money could be saved by installing roof bolts in this mine instead of using peg timbering.

One additional factor in favor of roof bolts was not discussed, as it is peculiar, more or less, to this mine. This factor is the tendency of the ribs

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to spall unduly. It has been found that the average entry in this mine will widen at the rate of approximately 1 foot a year. Each rib will spall approximately 6 inches annually. This tends to reduce the length of the hole in which the pegs are installed until posts have to be set under the pegs to insure support of the bearing rails and cross bars. Thus, an increased cost for supporting the roof automatically follows. However, it is thought that, with roof bolting, this factor will be eliminated as, with spalling of the ribs, additional roof bolts can be installed from time to time at very little additional expense.

The officials of this company spared no time, effort, or expense to see that the roof bolting was done as well as possible. A foreman was provided with the two-man crew at all times. Enough bolts were always installed, and, in many cases, it was thought that too many might have been used. The roof-bolting crew was instructed to install the bolts properly, regardless of how few they installed in a shift. This is another reason why the average number of bolts installed was so low. There was never any attempt to use shorter (cheaper) bolts than the pattern called for.

As a result of this policy, money was saved, and it is thought that this installation will stand for years with a minimum of maintenance.

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